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Modification and Deployment Techniques for Hand-Deployed Arctic Long-Life Sonobuoys

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(Invited Paper)

Abstract—**Underwater acoustic measurements made from the pack ice in Arctic regions often require unmanned remote hydrophones. The purpose may be to set up an under-ice acoustic tracking range, to avoid ice station generated noise, and/or to measure transmission loss. In any case, it is desirable to utilize a system that is reliable, low cost, easy to operate, rugged, and that requires no maintenance. These desirable traits can be satisfied by utilizing a hand-deployed remote hydrophone system based on modified sonobuoys. This paper presents specific methods and equipment used to modify, power, and hand-deploy AN/SSQ-57A sonobuoys in the Arctic. The methods and suggestions can be easily extended for use with other types of sonobuoys. The modified sonobuoys transmit continuously for up to 30 days from a remote unmanned site to a manned base camp over a range of 20 km. Sample acoustic data from the APLIS 87 ice station will be presented.**

I. Introduction

HIGH-QUALITY underwater acoustic measurements can be difficult to make because of contamination by unwanted noise sources. Very often the contamination is caused by the platform and/or equipment used to make the measurements (ship noise, cable strum, aircraft prop lines, etc.). Nowhere is the problem more evident than on the Arctic pack ice. Near an ice camp, electrical generators, footsteps, snowmobiles, and even conversations are acoustically coupled to the water column. These problems associated with underwater acoustic measurements can often be avoided by conducting the measurements at remote unmanned sites. However, unmanned sites can cause a variety of problems in the harsh Arctic environment; e.g., equipment failures and the high expenses associated with deployment and retrieval. A relatively low-cost alternative can be easily built from sonobuoys.

This paper addresses the use of sonobuoys as remote, hand-deployed hydrophones on the Arctic pack ice or in the Marginal Ice Zone. Sonobuoys have been used in the Arctic with varying degrees of success for several years. An exhaustive search of the literature found no papers addressing any of the issues involved with this type of Arctic sonobuoy deployment. Discussions with colleagues at other Arctic and U.S. Navy laboratories have shown a pattern of failures, few successes, and nothing in print describing any aspect of modifying and hand-deploying sonobuoys through the ice. This paper will describe sonobuoy modifications and deployment techiques that have worked well for NORDA's Arctic Acoustics Branch, and can be used as a starting point for those who have little or no experience with sonobuoys in the polar regions.

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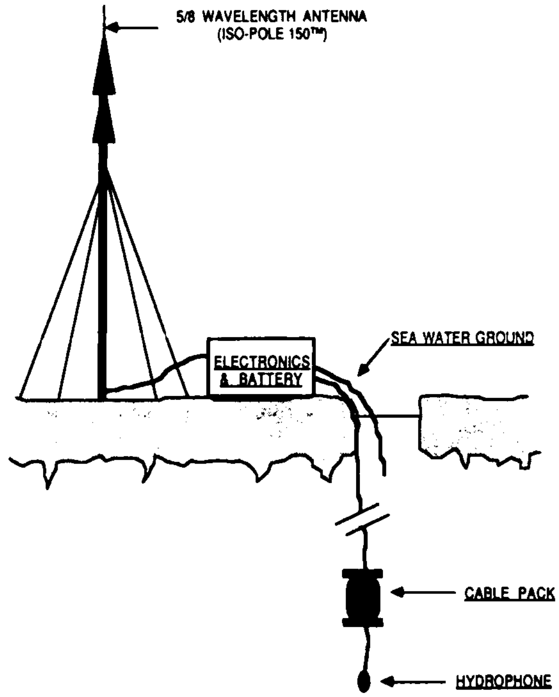


Fig. 1. Hand-deployed remote Arctic long-life sonobuoy.

Sonobuoys can provide a low-cost, easily deployed, reliable remote hydrophone capable of continuous (or intermittent, if so desired) data transmission for up to 30 days to a manned ice camp over a distance of up to 20 km. The methods described herein have been proven in the Arctic.

A typical Arctic hand-deployed sonobuoy configuration is shown in Fig. 1. The major components are the mast-mounted antenna, the modified sonobuoy electronics, and the battery pack.

II. Background

Sonobuoys are remote, lightweight, expendable, VHF radio-link sensors, available in three general catagories: Passive acoustic, active acoustic, and special purpose. The Sonobuoy Instructional Manual [1] lists all types currently available in the U.S. Navy supply system with a brief description of their characteristics. A variety of additional types of sensors (sound velocimeters, current profiles, etc.) are available for scientific purposes. The primary purpose of sonobuoys has not changed since their introduction by the British at the end of World War II; i.e., air-launched (from

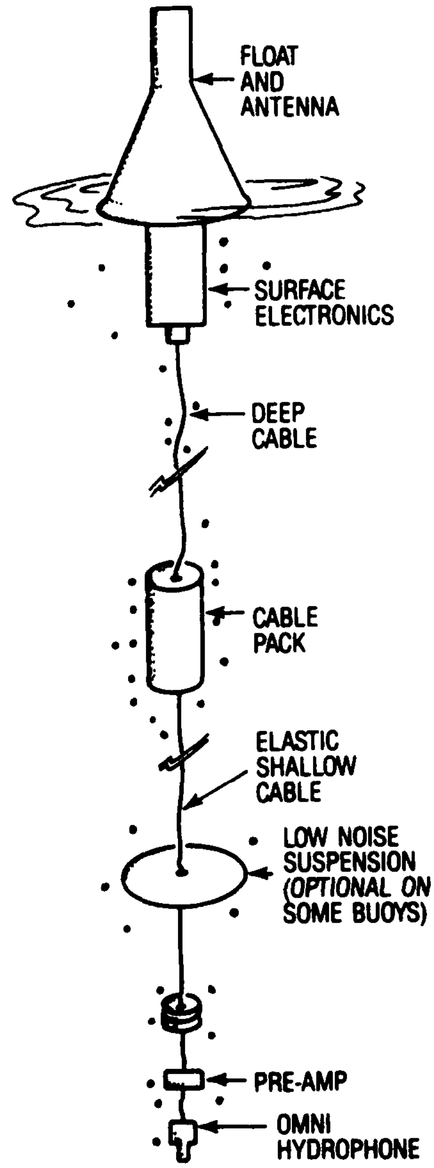


Fig. 2. Sparton AN/SSQ-57A sonobuoy in a normal 400-ft deployment configuration.

fixed or rotory wing aircraft) underwater sound detectors for antisubmarine warfare.

The basic design of any sonobuoy (see Fig. 2) consists of a subsurface sensor (usually one or more hydrophones and preamplifier assembly), cable assembly, battery pack (seawater or lithium), and surface electronics including the VHF transmitter and antenna. Most production sonobuoys are packaged in an "A" size sonobuoy container measuring 4-7/8 in (12.4 cm) diameter by 36-in (91.4 cm) length.

The second part of the sonobuoy system is the VHF sonobuoy receiver assembly which is usually installed in an aircraft or, in this case, at an ice camp or on an ice breaker. The receiver should be either a military sonobuoy receiver (AN/ARR-52, AN/ARR-72, AN/ARR-75, etc.) or a very high-quality, low noise commercially available FM receiver capable of handling the extreme bandwidths and multiplexing used in sonobuoy transmissions. A thorough knowledge of the receiver's characteristics and an extensive receiver calibration are mandatory for any acoustic sonobuoy work and cannot be over emphasized. Sonobuoy receiver systems will not be discussed in this paper.

III. Sonobuoy Modifications

Sonobuoy electronics are manufactured to meet performance specifications, not design specifications. Consequently, the design can and does vary between manufacturers, contract numbers, and occasionally even within a contract. It is, therefore, imperative that all alterations for Arctic deployment be made prior to shipment to the ice camp. The sonobuoys to be modified should be from the same manufacturer, the same contract number, and, if possible, the same lot number. All sonobuoys to be modified, along with an adequate number of identical replacements, should be isolated before starting any modifications to ensure that they are all of the same design and construction. The availability of calibration data should be confirmed prior to any modifications if calibrated sonobuoys are required. The modifications detailed in Appendix I were made to AN/SSQ-57A sonobuoys of the basic design manufactured by Sparton Electronics from 1979 (beginning with the 1978 contract number) to the present. The AN/SSQ-57A is a calibrated sonobuoy with an omnidirectional hydrophone deployable to a depth of up to 400 ft (122 m) through the ice. Appendix II presents operating specifications and characteristics of unaltered AN/SSQ-57A sonobuoys. The steps can be followed exactly if the contract numbers are from the contract years 1978 or later, and can be used as guidelines to modify *other contracts, manufacturers*, or types of sonobuoys. Care must be taken to prevent personal injury when modifying sonobuoys due to a variety of methods employed to erect antennas and deploy the hydrophones. Some sonobuoys use small explosive charges, compressed gases, strong springs, lithium batteries, or any combination of the above.

IV. External Power Systems

The best external power system to operate the sonobuoy depends on the type of sonobuoy, the expected temperature range, the deployment scheme, and the duration of the data-collection effort. The suggestions given here have been used with AN/SSQ-57A sonobuoys in the Arctic and can be used as guidelines. The AN/SSQ-57A is designed to operate from a 16-V dc seawater battery, and draws about 0.2 A at 16 V. It requires at least 9 V to function, and over 12 V to function properly. Table I shows the relationship between the input voltage at the battery wires, the current drawn, the radio frequency (RF) power out, and the effect of different voltage levels on the FM carrier-center frequency for AN/SSQ-57A's. Modified sonobuoys have been successfully deployed in the Arctic with input power voltages as low as 12 V and as high as 20 V.

Three battery types will be discussed: alkaline, gel-cell, and Stowaway [2]. Alkaline lantern batteries (6 V dc) can be used with three batteries in series to provide 18 V initially. Some advantages of alkaline batteries are that they are readily available, are easily configured into a variety of shapes, and are low in cost. The major problems are that the voltage falls off quickly with decreasing temperature (the reason for starting at 18 V), that you may not get fresh batteries so they

TABLE I
THE EFFECT OF INCREASING THE INPUT VOLTAGE OF AN AN/SSQ-57A SONOBUOY ON THE CURRENT DRAWN, THE RF POWER TRANSMITTED, AND THE SHIFT IN THE CENTER OF THE FM CARRIER FREQUENCY*

B+ (Volts)	I_t (Power Supply Current) (ma)	RF (Watts)	Δf_c (Center Frequency Change) (kHz)
10	110	0.28	-95
11	126	0.44	-58
12	152	0.59	-25
13	171	0.79	-4
14	187	0.94	-2
15	204	1.12	-1
16	220	1.31	0
17	236	1.53	1
18	252	1.73	2
19	267	1.93	4
20	283	2.13	5

* Reference [11].

may not be at the rated capacity, and if several "three packs" are put in parallel to obtain the required ampere-hour capacity, the configuration may get clumsy. The Procell PC 918 [3] is a high-capacity (40 Ah), 6-V industrial lantern battery (NEDA/ANSI 918 AC) that has proven to be the most versatile alkaline battery for sonobuoy deployment in the Arctic. Another common battery type frequently used in the Arctic is gel-cells. Gel-cells are available in a variety of shapes, capacities, and voltages; have good low-temperature characteristics; can be used in any orientation (on their side, upside down, etc.); and have performed well in the Arctic. Also, their capacity can be checked prior to deployment by discharging and recharging. The disadvantages are that they are more expensive and not as readily available as some other battery types. The last battery type to be discussed is a relatively recent development in commercially available batteries and is called the Stowaway. The Stowaway is a high-capacity, sealed lead-acid, deep-cycle marine battery in which the acid is held in a felt-like glass-fiber "sponge" material. This cell construction is called Absolyte [4] by the manufacturer and is a starved electrolyte technology. Low-temperature characteristics and testing of this battery can be found in Coia and Szymborski [5]. The advantages of the Stowaway battery are their very high-capacity, relatively low-cost, their use in any orientation, their being sealed maintenance free, ability to withstand by freezing, leak-proof, and that are available in 4, 6, and 12 V. The disadvantages are that they are currently available in a limited number of sizes and shapes and have not been certified for air transport (they have passed all tests and certification is expected).

Two major methods of configuring the batteries have been used. If the expected temperatures are very low, then the alkaline batteries or gel-cells are packed in polyvinyl chloride (PVC) schedule 40 pipe to provide a waterproof battery case. The Procell PC 918 batteries fit very nicely inside 6-in (15.2 cm) diameter PVC pipe when stacked on top of each other and taped to a 2-in (5.1 cm) × 4-in (10.2 cm) piece of lumber. The 6-in diameter PVC pipe is easily lowered into a 9- or 10-in (22.9-25.4 cm) diameter ice hole drilled next to the hydrophone ice hole. The battery hole should be drilled after the hydrophone hole to about a foot from the water-ice interface. This will prevent any chance of the battery case adding acoustical noise or tangling with the hydrophone wire, and will simplify the deployment procedure. The battery case may need weight added so it will not float as water seeps into the hole prior to freezing, and should be tied off at the surface in case the ice at the bottom of the hole is too weak to hold the weight of the batteries. If the hydrophone ice hole is used for the battery ice hole, great care must be taken not to pinch or crush the very delicate hydrophone wire, and the battery case should be tied off at the surface so that it doesn't hang into the water column. If the expected low is above about −25° C, then the batteries can be left on the ice surface with the transmitter electronics in their insulated ice-chest shipping container.

V. ANTENNAS

The choices for antenna system designs and manufacturers are almost endless. Antenna systems should be kept simple, especially at a remote location. The only reliable RF signal path in the sonobuoy very high-frequency (VHF) range in the Arctic is line of sight. The Arctic pack ice is in general a very poor and variable electrical conductor [6]-[8] because of its multiyear structure; i.e., open leads that are highly saline ocean water and, therefore, very conductive, refrozen melt ponds and snow that are very good insulators, and ice rubble, consisting of a little of each piled several meters high, scattered throughout. Atmospheric reflection and refraction are extremely unreliable, and there are variable RF signal paths at any frequency in the Arctic because of the effects of the earth's magnetic field at these latitudes and also of the Aurora Borealis.

A. Antenna Directionality

The signal strength gained by the use of horizontally directional antennas for the transmitting antenna may change to a loss as ice flows translate and rotate; therefore, horizontally directional antennas should be avoided for most applications. However, the receiving antenna may be horizontally directional if all the sonobuoys are located in a single direction or if one does not need continuous coverage from all sonobuoys simultaneously. Our experience indicates that the best choice for both transmitting and receiving are horizontally omnidirectional antennas. Vertical directionality can be used effectively to gain a few decibels in signal strength, but, again, use caution in choosing the proper antenna for a specific application. The best choice for a transmitting antenna when the receiving antenna is located at an ice camp or on an ice breaker is a 5/8 wavelength whip antenna because of the relatively flat lobes of the radiation pattern. The Iso-Pole 150 [9] has proven to be a good choice for transmission to ice camps. It is a 5/8 wavelength design with a small cross-sectional area (for low-wind resistance), sturdy construction, and is easily deployed in the field. The Iso-Pole design provides a flatter, more predictable radiation pattern than other low-cost antennas, and a broader RF-frequency coverage. The only drawback is that the pre-assembly takes a little longer than most whip antennas and should be done at the ice

camp, not at the remote sonobuoy location. If the sonobuoy will be transmitting to an airborne receiver, then a 1/4 wavelength whip with three or four radials should be used to increase the RF-power radiated skyward. The ASP-7A antenna (by Antenna Specialists Co.) is an inexpensive, 1/4 wavelength design with four radials which is simple to assemble in the field. If both ice camp and airborne receivers are involved, the 1/4 wavelength whip theoretically should outperform the Iso-Pole. It should be noted that both types of recommended antennas have been used in the Arctic to transmit to aircraft, and both have performed satisfactorily, but no side-by-side comparisons of signal-strength to aircraft have been made. Other important considerations in choosing the best antenna are ruggedness, wind resistance, and ease of assembly.

B. Antenna Height

The sonobuoy carrier frequencies are in the VHF range and should, therefore, be considered "line of sight." The following simple formula has proven to be adequate for determining the minimum antenna height needed for a given distance:

$$D=(h_r)^{1/2}+(h_t-h_i)^{1/2} \tag{1}$$

where

- h_r height of the receiving antenna in feet,
- h_t height of the transmitting antenna in feet,
- h_i height of the ice rubble between the antennas in feet,
- D maximum reliable transmitting distance in nautical miles.

Equation (1) is a conservative, simplified, line-of-sight equation with a factor h_i subtracted from the transmitting antenna height to allow for the height of ice rubble between the antennas (an explanation of the formula is given in Appendix III). For example, with a 25-ft (7.6 m) mast at the sonobuoy, a 36-ft (11 m) mast at the ice camp, and an estimated ice-rubble height of 10 ft (3 m),

$$D=36^{1/2}+(25-10)^{1/2}=9.9 \text{ nmi}. \tag{2}$$

The distance might be increased with the use of repeaters, but to date this has not been tried at NORDA.

C. Mast Construction

The next antenna-related question regards antenna mast construction. Base camp antennas can be easily mounted on top of a 36-ft (11 m) telescoping, TV type, antenna mast. This type of mast is strong, easily erected, and relatively cheap. It can be securely attached to the side of a plywood instrument hut, with guy lines running to the hut corners, thus eliminating the danger of tripping over them. If there is nothing rigid on which to attach the antenna mast, it can be erected as a free-standing mast, with its base frozen into a 6- to 12-(15.2–30.5 cm) in-deep ice hole. If an Iso-Pole antenna is used as the receiving antenna there must be enough room for the lead-in coaxial cable to be threaded through the center of the antenna mast. A Radio Shack [9] part number 15–5067 works well. Remote transmitting antenna masts should be constructed of easily erected sections. The lengths of the sections may depend on the mode of transport used for remote deployment; e.g., snow mobile, helicopter, etc. Again, if the Iso-Pole antenna is used, be sure that the coaxial cable will fit down the center of the mast. A good choice here is Radio Shack part number 15–842 or the equivalent. It is a 5-ft long (1.5 m), 1.25-in-diameter (3.2 cm) interlocking section, packaged ten to a box. A number of companies make mast sections similar to the Radio Shack model, but some interlocking methods do not allow the coaxial cable to be passed through their length without alterations. (Note: A PL–259 to BNC adapter should be put on the antenna (especially if an Iso-Pole is used) prior to going to the field because it is much easier to twist on a BNC connector than to screw on a PL–259 when attaching the coaxial cable.)

TABLE II
LIST OF ITEMS TO BE INCLUDED ON THE TOOL SLED

Power ice drill and associated equipment
Ice scoop
Tool box
Hand auger
Rechargeable drill and/or hand drill

TABLE III
LIST OF ITEMS TO BE INCLUDED IN THE EXPENDABLE EQUIPMENT BOX

Modified sonobuoy
Battery pack
Guy lines (parachute cord) and mast ring
Large nails or other suitable guy line stakes
Antenna coaxial cable
Battery power lines

VI. Field Deployment

The remote sonobuoys are easily deployed by two people. The addition of a third person cuts the working time in half, therefore it is both advisable and cost effective if deployment is done using a helicopter. The helicopter method is described and should be used for deployments beyond a few thousand meters from the ice camp, if possible. A banana sled makes an excellent tool sled that is easily loaded into the helicopter or pulled behind a snowmobile. It should contain all nonexpendable tools and equipment required at each deployment site (Table II). The expendable equipment should be packed in separate containers, each with only the equipment needed at a single site (Table III), and marked with the sonobuoy channel number on the outside. Thirty-five to 40-quart ice chests make very good low-cost containers for remote deployment. They are tough at low temperatures, can be used for shipping from the laboratory, can be considered expendable (available for under $20), and provide good protection for batteries and electronics. Antenna mast sections should be limited to a length of 5 ft for most helicopter deployments to ensure that they fit easily inside the cargo bay.

All sonobuoys, batteries, etc., should be checked and have as much assembly done as possible before takeoff. This

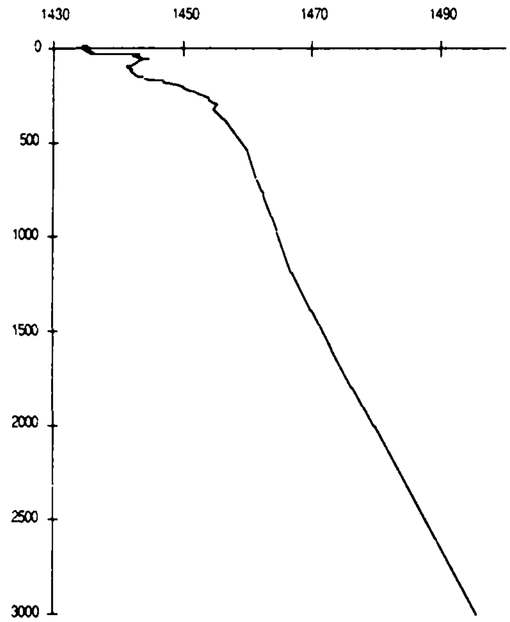


Fig. 3. Sound-speed profile from the APLIS 87 ice camp. Surface to 300 m is measured data with historical data to the bottom.

TABLE IV
COMPARISON OF THE DISTANCES TRAVELED, TRAVEL TIMES COMPUTED, AND TRAVEL TIMES MEASURED FOR SHOT DATA SHOWN IN FIG. 4

TRACE	DISTANCE(km) DIR	BB	COMPUTED(sec) DIR	BB	MEASURED(sec) DIR	BB
a)	0.0	5.856	0.00	4.0	0.0	3.7
b)	0.3	6.008	0.21	4.1	0.2	3.8
c)	8.2	10.161	5.68	7.0	5.7	6.8
d)	13.9	15.140	9.63	10.4	9.7	10.2

"DIR" is the direct path and "BB" is the bottom bounce.

includes installing the antenna on the top-mast section, installing battery leads with straight, insulated, female, quick-connect terminals (or other suitable connectors) on the batteries, etc. Details of the field-deployment procedure are given in Appendix IV.

VII. Sample Data

Data recorded from remote sonobuoys at the APLIS 87 ice camp consisted of ambient sea noise, transmission loss, and relative RF signal strength. The sample data presented here is a single shot with the source being an imploding 90-W light bulb dropped through an ice hole at the instrumentation shelter. The start time for the event was determined from an unaltered AN/SSQ-57A sonobuoy deployed to a depth of 60 ft (18 m) through the same hole in which the sound source was lowered. The remote sonobuoy hydrophones were each deployed to a depth of 60 ft (18 m) and located in a straight line from the source at distances of 0.3, 8.2, and 13.9 km. The estimated water depth from bathimetry charts was 2950 m. Fig. 3 is the sound-speed profile measured to 300 m and merged with historical data to the bottom. Table IV compares the calculated travel times for each slot with the measured times from the strip-chart record shown in Fig. 4. Fig. 4 is a strip-chart record of the broadband arrivals with identical gain settings for each channel. Trace (a) shows the signal of the unaltered sonobuoy (co-located with the sound source) that was used as the start time and a bottom-bounce return 3.7-s later. Note the increase in amplitude of the background noise of trace (a) as a result of the electrical generator at the instrumentation shelter. Traces (b) (0.3 km), (c) (8.2 km), and (d) (13.9 km) show the direct path arrival after 0.2, 5.7, and 9.7 s and the bottom-bounce arrival after 3.8, 6.8, and 10.2 s, respectively.

The relative RF signal-strength measurements indicated a stronger RF signal received from the transmitter at 13.9 km than from the transmitter located at 8.2 km. The difference between the two transmitters was that the farthest one had a 25-ft (7.6 m) mast and an Iso-Pole antenna, while the closer one had a 15-ft mast with a 1/4 wavelength antenna. This illustrates the importance of the ice-rubble term in (1).

VIII. Conclusion

Simple modifications can be made to sonobuoys that will make them excellent low-cost, remote hydrophones for a variety of uses on the Arctic pack ice and in the Marginal Ice Zone. Some applications for the sonobuoy system include an under-ice acoustic-tracking range, transmission loss measurements, and spacial variability of under-ice ambient noise.

Appendix I

If there is any question as to what is involved in making the following modifications, check with the manufacturer. It is assumed that the user is somewhat familiar with sonobuoys. The following steps begin with the sonobuoy removed from the plastic SLC (Sonobuoy Launch Container):

1) Record the manufacturer, contract number, lot number, serial number, and channel number of the sonobuoy before beginning any alterations.
2) Disengage the wind flap, pull out the parachute, cut it off, and discard it.
3) Pass a strong piece of nylon strap, parachute cord, etc., under the cross member at the bottom of the plastic cap in which the parachute was packed, and form a loop. Place the loop over a strong stationary object (shop vise handle, doorknob, etc.) and give a sharp, hard jerk on the sonobuoy. This will simulate the antenna bag inflating and pop-out the end cap.
4) Make sure the depth setting is shallow, and turn the sonobuoy upside down on a workbench. Pull-off the outer aluminum canister. Tape the hydrophone and preamplifier assembly in place in the bottom of the hydroplane cable pack before turning the sonobuoy upright.
5) Mark the sonobuoy with all pertinent data (contract number, lot number, serial number, and channel number), using a permanent method, i.e., paint, whiteout, waterproof sticky label, etc.
6) NOTE: ALL REFERENCES TO RIGHT OR LEFT WILL BE WITH THE POSITIVE (WHITE) BATTERY WIRE TO THE LEFT AND THE NEGATIVE (BLACK) WIRE TO THE RIGHT. This will place the 1-, 3-, 8-h timer switch towards you.

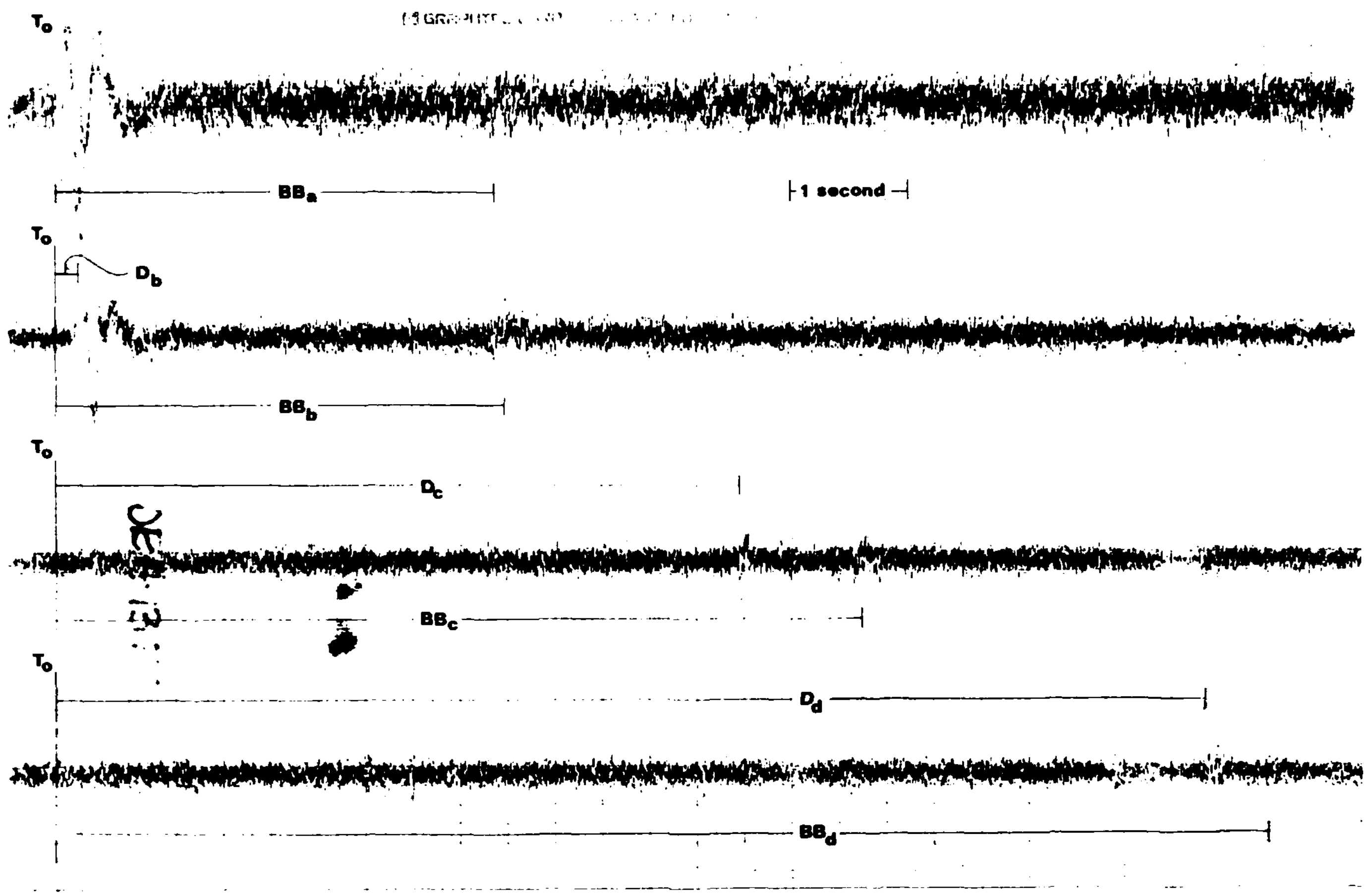
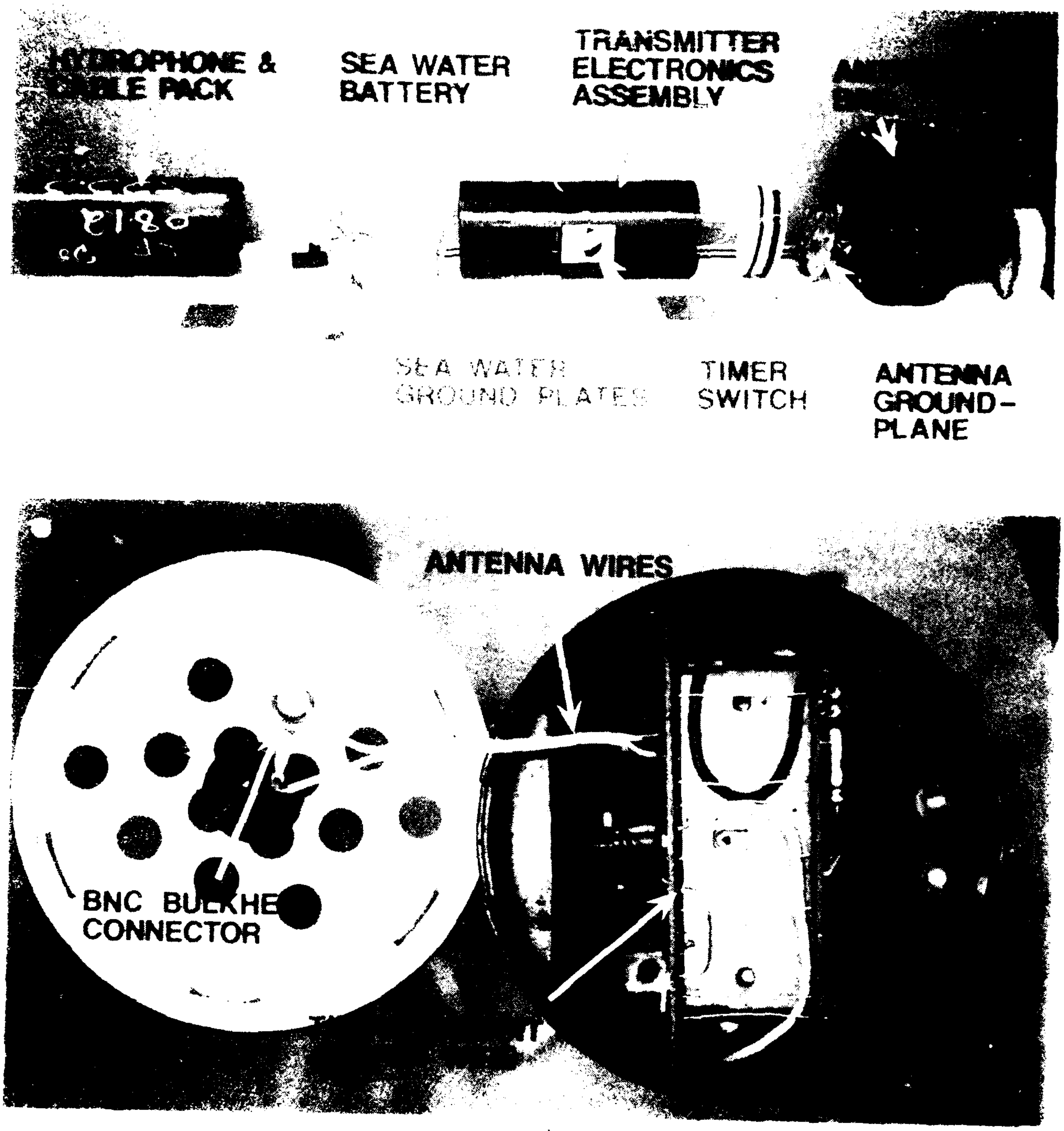


Fig. 4. Strip-chart record of a single broadband sonobuoy shot signal with sonobuoy hydrophones located at (a) 0.0 km, (b) 0.3 km, (c) 8.2 km, and (d) 13.9 km from the source. "D" represents the direct path arrivals and "BB" represents the bottom-bounce arrivals.

7) CAUTION: READ THIS STEP CAREFULLY BEFORE PROCEEDING. The following steps must be very carefully followed to prevent possible injury. Cut the positive (white) battery wire as close to the seawater battery as possible. Attach a jumper wire at least 1-m long to the positive battery lead and another to the termination of the negative (black) lead at the galvanized seawater ground plate on the right-side of the seawater battery. STAND CLEAR OF THE SONOBUOY! Apply at least 12-V dc across the jumpers. The antenna float bag will inflate when a resistor wire burns in two, releasing a firing pin that fires a 0.22-caliber blank cartridge. This in turn drives a two-pronged activator into dual carbon dioxide cartridges that inflate the antenna bag with great force. The force will launch the plastic cap that covers the antenna bag assembly several meters into the air, and would blow-out the parachute assembly if it had not been removed in step 3. The bag may inflate immediately upon power being applied or it may take several seconds. If the bag does not inflate within 30 s, CUT THE POWER TO THE SONOBUOY BEFORE INVESTIGATING THE PROBLEM! Check the connections at the sonobuoy and try applying power again until the bag inflates.
8) Cut the antenna bag off at its base with a razor knife, cut-off the antenna wire (the white two-conductor zip cord contained in the antenna bag) just below the plastic strain relief, and cut the strain relief wires at the galvanized metal antenna ground plane (see Fig. 5). Discard the antenna bag.
9) Cut the black battery wire where it is bolted to the galvanized seawater ground plate.
10) Remove the two 1/4-in self-tapping screws that hold the transmitter section (upper section) to the hydrophone cable pack (lower section); they are located just below the battery compartment. Remove the transmitter section, turn it over to expose the battery, and remove the battery. Cut the thin, unshielded pink wire. DO NOT CUT THE PINK WIRE WITH THE CLEAR PROTECTIVE JACKET! It is the hydrophone wire. Put the two sections of the sonobuoy back together with the 1/4-in self-tapping screws.
11) Remove the four small white plastic clips that hold the antenna bag compartment in place and pry the antenna bag compartment off. Remove the rectangular cardboard insulator and save it for later replacement. Install a BNC bulkhead connector on the white plastic antenna bag housing (see Fig. 6).
12) NOTE: Remember that all references to the right or left will be with the white battery wire to the left. Locate the fourth uninsulated jumper wire from the left (there will be a total of eight uninsulated jumper wires


SEA WATER BATTERY
TRANSMITTER ELECTRONICS ASSEMBLY
SEA WATER GROUND PLATES
TIMER SWITCH
ANTENNA GROUND-PLANE
ANTENNA WIRES
BNC BULKHE
CONNECTOR

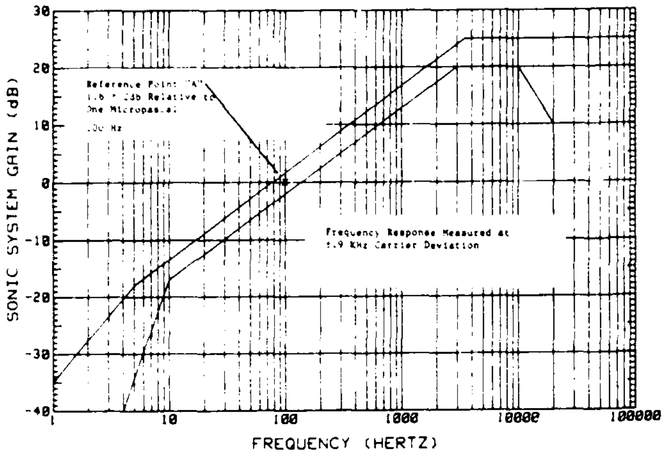


Fig. 7. Frequency response envelope for AN/SSQ-57A (FY 79 and later).

call for other options, such as completely removing the electronics from the transmitter housing for repackaging in a more suitable or watertight container.

Appendix II

The following discussion of operating specifications and characteristics was condensed from the military specification for AN/SSQ-57A sonobuoys [12] and also from many years of experience. If the modifications for Arctic use are followed as outlined, these acoustic characteristics will not be affected.

The acoustic bandwidth of an AN/SSQ-57A sonobuoy is 10 Hz to 20 kHz. The hydrophone response is flat within ± 1 dB and omnidirectional within ± 1 dB from 10 Hz to 10 kHz. The sonic receive system is defined as all elements that pass acoustic energy from the ocean through the VHF transmitter, and is usually referred to as the sonobuoy. Although the hydrophone response is flat, the acoustic response of the system is not. It is pre-emphasized (often referred to as pre-whitening), that is, the high frequencies are amplified relative to the low frequencies to "flatten" the natural shape of the ambient sea-noise spectrum and, therefore, improve the dynamic range (which is considered to be better than 60 dB) and signal-to-noise ratio over the useful frequency range of the sonobuoy. The slope after pre-emphisis is 4.5 dB per octave from 10 Hz to 3 kHz. The acoustic response of the sonobuoy falls within the envelope shown in Fig. 7.

The VHF transmitter is preset by the manufacturer to one of the standard 31 sonobuoy channels. The VHF frequencies range from 162.25 (chan. 1) to 173.5 MHz (chan. 16), spaced 375 kHz apart in a chan. 1, chan. 17, chan. 2, chan. 18, ··· chan. 31, chan. 16 sequence. (Note: Originally there were sixteen channels spaced 750-kHz apart; when more channels were needed, fifteen channels were added by splitting the sixteen original frequencies. The total number is now 99 channels. This was accomplished by dropping chan. 32 to 136 MHz and running up to chan. 99 at 161.125 MHz, and leaving the original 31 channels as previously assigned. The 375 kHz separation is maintained.) The VHF carrier must be capable of being frequency modulated over the entire frequency range from 10 Hz to 20 kHz. The VHF carrier deviation will not exceed ± 105 kHz when subjected to a voltage level 15 dB above that required to produce a ± 75 kHz deviation.

TABLE V
EXAMPLE OF AN/SSQ-57A CALIBRATION DATA*

SPARTON ELECTRONICS
CONTRACT NOO163-82-C0068
LOT # 01

a) Serial	ch	sens	10	30	50	100	200	300	500	1k	2k	5k	10k	20k
b) #	#	-dBv	-dB	-dB	-dB	+dB	+dB	+dB	+dB	+dB	+dB	+dB	+dB	+dB
c) 0001	01	155.6	14.4	7.0	4.9	0.0	4.8	7.1	10.6	14.9	20.0	27.0	21.5	21.9

* Where row a) is the column headings of serial number, channel number, and test frequency in Hz. The sign in front of each dB heading in row b) denotes the sign of the number below it, usually negative for frequencies below 100 Hz and positive for frequencies above 100 Hz. Row c) gives the individual sonobuoy serial number, channel number, and calibration level. The column under 100 Hz should always be 0.0.

AN/SSQ-57A sonobuoys are designed for the accurate measurement of underwater sound intensity and, therefore, must be calibrated by the manufacturer. Some modifications to the standard AN/SSQ-57A exist for specialized use and are not calibrated, e.g., XN-5's, desensitized shot sonobuoys, etc. The calibration data must fall within the envelope shown in Fig. 7, be repeatable by the manufacturer to within ± 1.0 dB, and be repeatable by any calibration facility to within ± 2.0 dB. Table V is an example of how the calibration data is reported to the user. Calibration data is usually supplied as a complete set containing all data for a given lot, which can contain from several hundred to several thousand sonobuoys. The frequency response reference point is 116 ± 2.0 dB relative to one micropascal (μPa) at 100 Hz which will produce a carrier deviation frequency of ± 19 kHz. (Note: Early contracts were referenced to a ± 19 kHz deviation equivalent to 106 ± 2 dB at 440 Hz relative to 1 μPa, which is the same specification written to a higher-reference frequency. The 100-Hz reference point is adjusted to zero and then checked at all the other frequencies.) A "standard curve" is often used in place of individual calibration data, but this should only be used between about 20 Hz and 10 kHz, and is obviously not as accurate as the individual calibration curves. At frequencies above 10 kHz, the spread in the values becomes too great to rely on a standard curve. Calibration information should always be obtained prior to deployment. It is strongly recommended that the individual calibration curves be used if high-quality data is desired. If a standard curve is sufficient, then each sonobuoy's individual calibration data should be checked for anomalous data points prior to deployment to verify that it closely fits the standard curve over the frequencies of interest. Any sonobuoys that do not closely fit the standard curve should not be used.

Although AN/SSQ-57A sonobuoys are specified and calibrated down to 10 Hz, 20 Hz is considered to be the lowest usable frequency for most purposes. The reason is that mechanical noise (cable strum, flow noise, etc.) can compromise the quality of the data at low frequencies. The hydrophone suspension system, which is the problem with cable strum, has been greatly improved, but the military specifications still allows mechanical noise at a maximum of 80 dB/μPa at 10 Hz, and electrical noise as high as 68 dB/μPa at 10